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THE HYDROGRAPHIC AIRBORNE LASER SOUNDER (HALS)

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BIOGRAPHICAL SKETCH

Stephen M. Webb is a Physical Scientist with the Systems and Techniques Directorate, Advanced Technology Division of the Headquarters, Defense Mapping Agency. He obtained his B.S. degree in geology from Oregon State University in 1964. He has worked for the Aeronautical Chart and Information Center as a photogrammetrist and the Naval Oceanographic Office as an oceanographer before coming to DMA. His present duties include assisting in the management of research and development programs pertaining to hydrographic data collection.

ABSTRACT

To provide an increase in hydrographic survey resources the Hydrographic Airborne Laser Sounder is being developed by the Naval Ocean Research and Development Activity (NORDA) under the sponsorship of the Defense Mapping Agency (DMA). The HALS system incorporates a pulsed, scanning blue-green laser and will be flown in a helicopter from a survey ship operated by the U.S. Naval Oceanographic Office (NAVOCEANO). Through the use of statistics in post-flight processing the HALS data will meet survey accuracy standards, more than adequate for safe navigation. NORDA will perform a technical evaluation of HALS and then turn the system over to NAVOCEANO for operation in late 1983.

INTRODUCTION

There is serious concern in the international hydrographic community that existing survey resources are too limited to perform the detailed broad area surveys required for new chart editions to be produced in the 1980s and beyond. While state-of-the-art hydrographic surveying methods and systems result in accurate depiction of the ocean floor, there is a great need to drastically increase the data collection rate and cost effectiveness of survey operations.

The Defense Mapping Agency (DMA) has been investigating a number of new charting tools, and their associated cost efficiency, that may provide a partial solution to the above dilemma. Hydrographic data collection technologies involving remote sensors and electro-optical techniques provide the greatest potential for collecting large amounts of hydrographic data very rapidly over shallow coastal waters. Remote areas that are too costly to reach by survey ships or otherwise inaccessible would be prime targets for exploitation of these new systems.

One remote sensing system now under development by the Naval Ocean Research and Development Activity (NORDA) under the sponsorship of DMA is the Hydrographic Airborne Laser Sounder (HALS) System. As can be seen from the HALS performance requirements in Table 1 the system will gather large amounts of hydrographic data in a short time. HALS is expected to increase a survey ship's productivity by 30%.

HALS SYSTEM

The HALS system is an airborne laser bathymeter consisting of a scanning beam pulsed laser which measures water depth. As the laser energy emitted from the system strikes the water surface, part of it reflects off the surface and part is transmitted through the water column to the bottom. If the water is not too deep or too turbid, some of the light reflects from the bottom and a receiver in the aircraft detects the reflected light and measures the time delay between the surface and bottom reflections (Figure 1). This time delay is then used to compute water depth. Depending on conditions of water clarity, the HALS will be able to measure depths from a minimum of .5 meters to a maximum of 50 meters.

Hardware. The major components of the HALS assembly include a laser transmitter, scanner, receiver, preprocessor, orientation sensing device, clock, horizontal positioning system and recorder (Figure 2).

The HALS laser transmitter is a frequency doubled neodymium doped yttrium-aluminum-garnet laser (Nd:YAC) transmitting at a wavelength of 530 nanometers. This wavelength is optimal for penetration of most coastal water types. The pulse repetition rate is 400 hertz with a pulse width of approximately 5 nanoseconds. These specific performance requirements for the laser were chosen to maximize the signal to noise ratio and resolution of shallow water depths.

The HALS scanner assembly consists principally of a rotating mirror with a constant rotation rate (Figure 3). The elliptical scan pattern which results provides both the necessary data coverage and a means of determining the aircraft attitude.

The horizontal positioning system used by HALS will be the Cubic Western ARGO Model DM-54 medium range system. In addition, the HALS will be compatible with, and an interface provided for, the Del Norte "Flying Flagman" short range positioning system. The short range system will be used for surveys made at scales of 1/25,000 or larger. In order to determine the horizontal placement of each sounding, the aircraft pitch, roll, heading and scanner orientation is recorded at the instant the sounding is made.

Data Processing. NORDA has the responsibility to develop the HALS postprocessing software. Actual depth soundings and horizontal placement of the soundings will be accomplished during post-mission data processing. Several types of data will be made available by the HALS. Individual laser soundings (Figure 4) will be plotted by the postprocessing system. Additionally, the data will be gridded at a selectable grid spacing with depths assigned to grid locations based on all measured depths in the four adjacent grid cells. The gridding will be accomplished by a two dimensional optimal filter which will deal with both depth and horizontal position errors simultaneously. The purpose of this gridding is to reduce sounding density and improve data quality to ensure its adequacy for safe navigation. Shallower depths and soundings depths closer to grid intersections will be weighted more heavily in determining depth values for the grid location, thus providing in a deliberate conservative bias toward the shallow depths.

Data quality parameters will be computed for each gridded value, permitting evaluation by the hydrographer of overall data quality. Areas that show poor data quality would be scheduled for resurvey with the HALS at increased data density by reducing scan rate, flight speed and/or altitude. An interactive ability to edit digital HALS data and merge it with digital data collected by the survey ship and launches is being developed concurrently.

OPERATIONS

Operational deployment of the HALS is scheduled for 1983 in the SH-2D helicopter (Figure 5) attached to the coastal survey vessel USNS HARKNESS. The system will be flown at altitudes from 150 to 1000 meters and speeds from 0 to 60 meters per

second. The scan angle will be variable from 0 to 25 degrees and will, along with flight speed and altitude, be used to determine the data density. Average density will be at least one sounding per 20 square meters, with increased coverage required for larger scale surveys. There will be three operational types of HALS missions: cross-check lines, principal survey lines, and saturation surveys (Figure 6). Cross-check lines will be run perpendicular to the depth contours; principal survey lines will be run nearly parallel to depth contours to maximize their length. Saturation surveys for shoals and hazardous areas will be run at low speed to increase data density.

HALS DEVELOPMENT SCHEDULE

NORDA prepared the system specifications in 1978. AVCO Everett Research Laboratory (AERL) was selected as the prime HALS contractor in September, 1979. Under the terms of the contract AERL will design, fabricate and test HALS with delivery to NORDA in late 1982. AERL should complete system integration by 1 March and environmental test by mid-May 1982. Following field acceptance tests which AERL estimates will be finished by 1 October, NORDA will conduct an intensive technical evaluation lasting from six to twelve months. At the conclusion of this technical evaluation NAVOCEANO will run operational evaluations and then start survey operation in late 1983. As soon as the NAVSTAR Global Positioning System (GPS) becomes available, about 1988, HALS will be deployed in a fixed wing aircraft. A second generation HALS using a high pulse rate (>5000hz) metal vapor laser is projected to be available at about the same time. The result will be an extremely capable survey system.

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TABLE 1

HALS PERFORMANCE REQUIREMENTS

Altitude	100 to 800 m; 150 m nominal.
Forward Velocity	37 m/s nominal.
Vertical Depth	0.5m to 50m; 20 m required at maximum scan angle for $K^* = 0.16 \text{ m}^{-1}$).
Slant Range Measuring Accuracy	
Altitude	$\pm 0.01\text{m}$ or 0.05% of range (larger).
Water Depth	$\pm 0.28\text{M}$ for depth from 0.5 to 20 M; ± 1.0 for depths $> 20 \text{ m}$.
Area Coverage	One sounding per 20 m^2 (average) at an altitude of 150 m, velocity of 37 m/s and maximum scan angle. Also, one sounding in every circle of 9 m diameter.
Scan Angle	Variable, 0 to 624 mrad.
Sea State	Operation to Beaufort 3 wind conditions.
Solar Angle	Operation at zenith angles $> 46^\circ$
Horizontal Position Accuracy	1.65 sigma value of 1.5 mm times the scale of survey.

* K = diffuse optical attenuation coefficient; $I = I_0 e^{-KZ}$

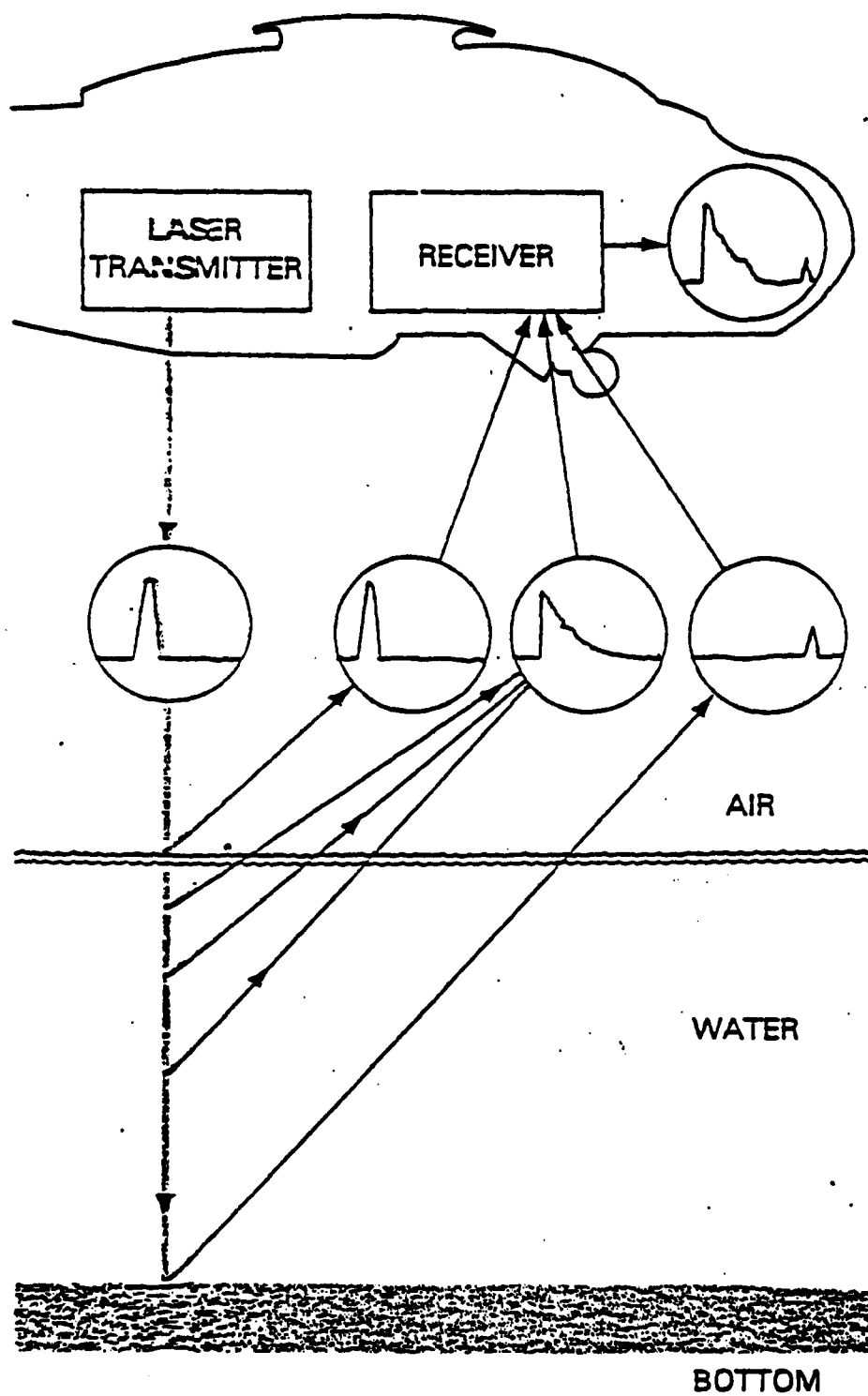


Figure 1-2

Figure 1

HALS transmitted and return waveforms.

AIRCRAFT HARDWARE

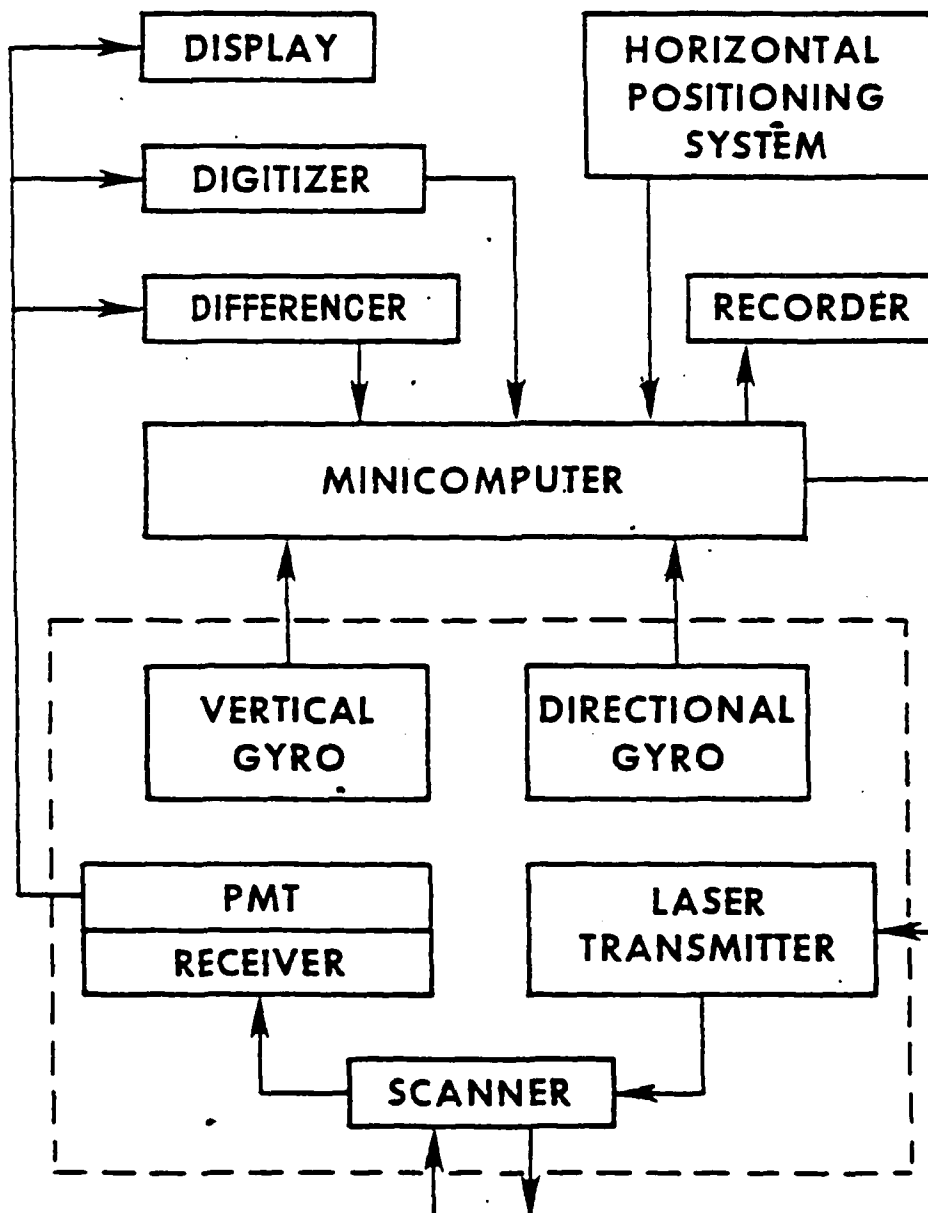
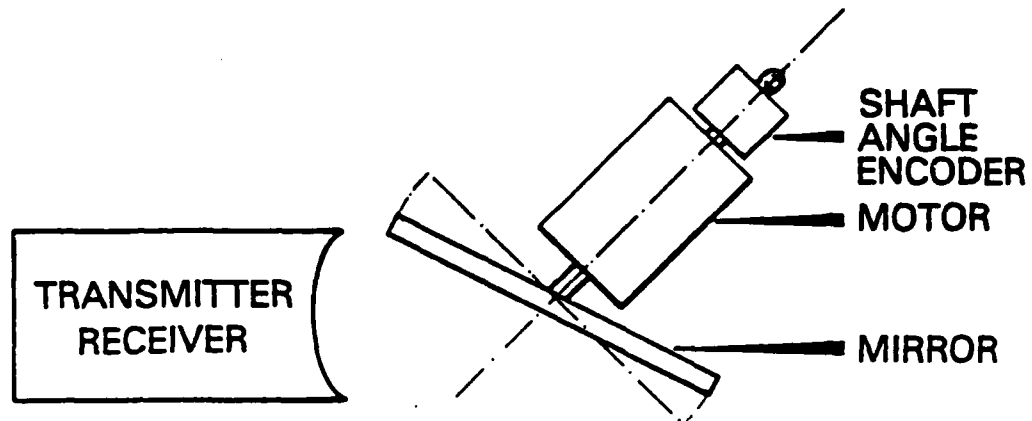


Figure 2

HALS hardware block diagram

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SCAN PATTERN PRODUCED

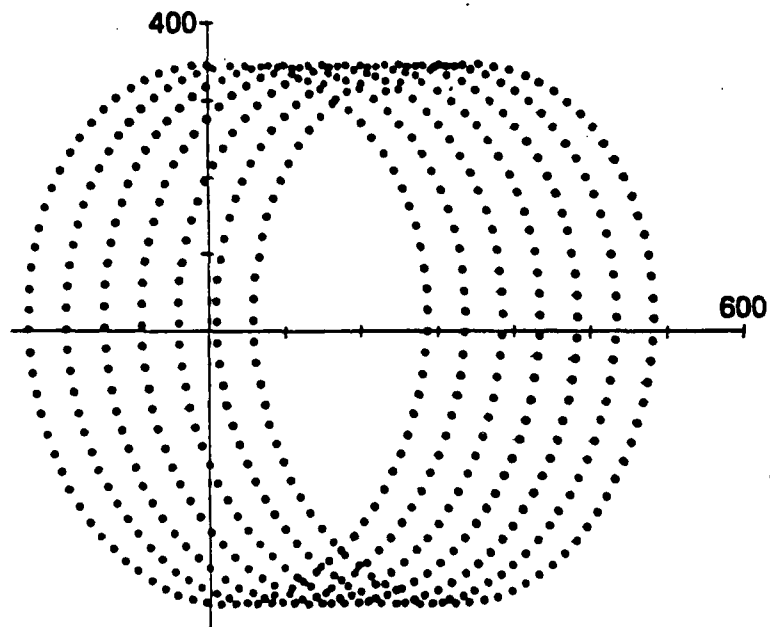


Figure 3 HALS scanner mirror and scan pattern

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Data Swath (scan pattern)

Figure 4 **Data printout of HALS swath path**

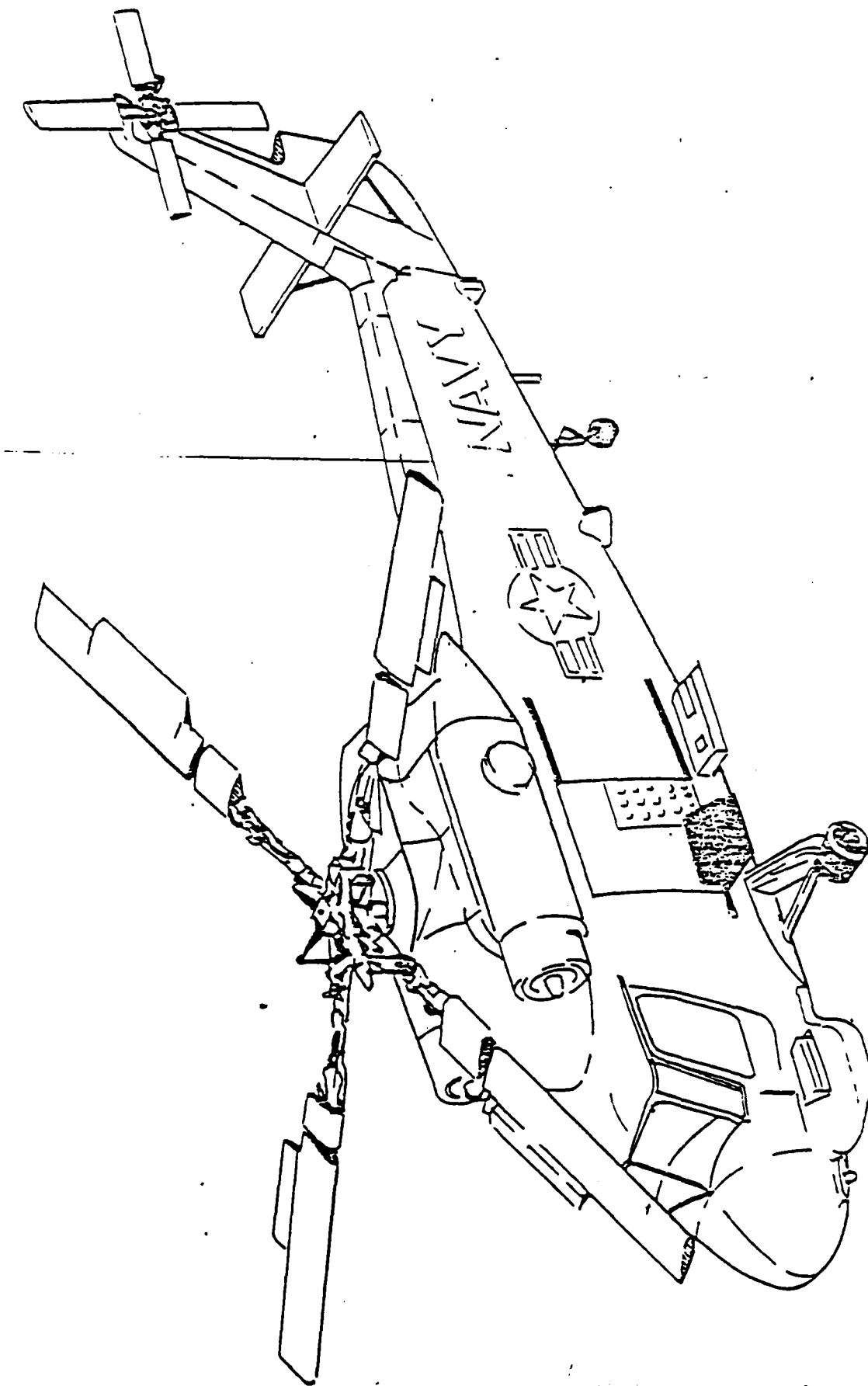


Figure 5 SH-2D helicopter with HALS mounted in doorway

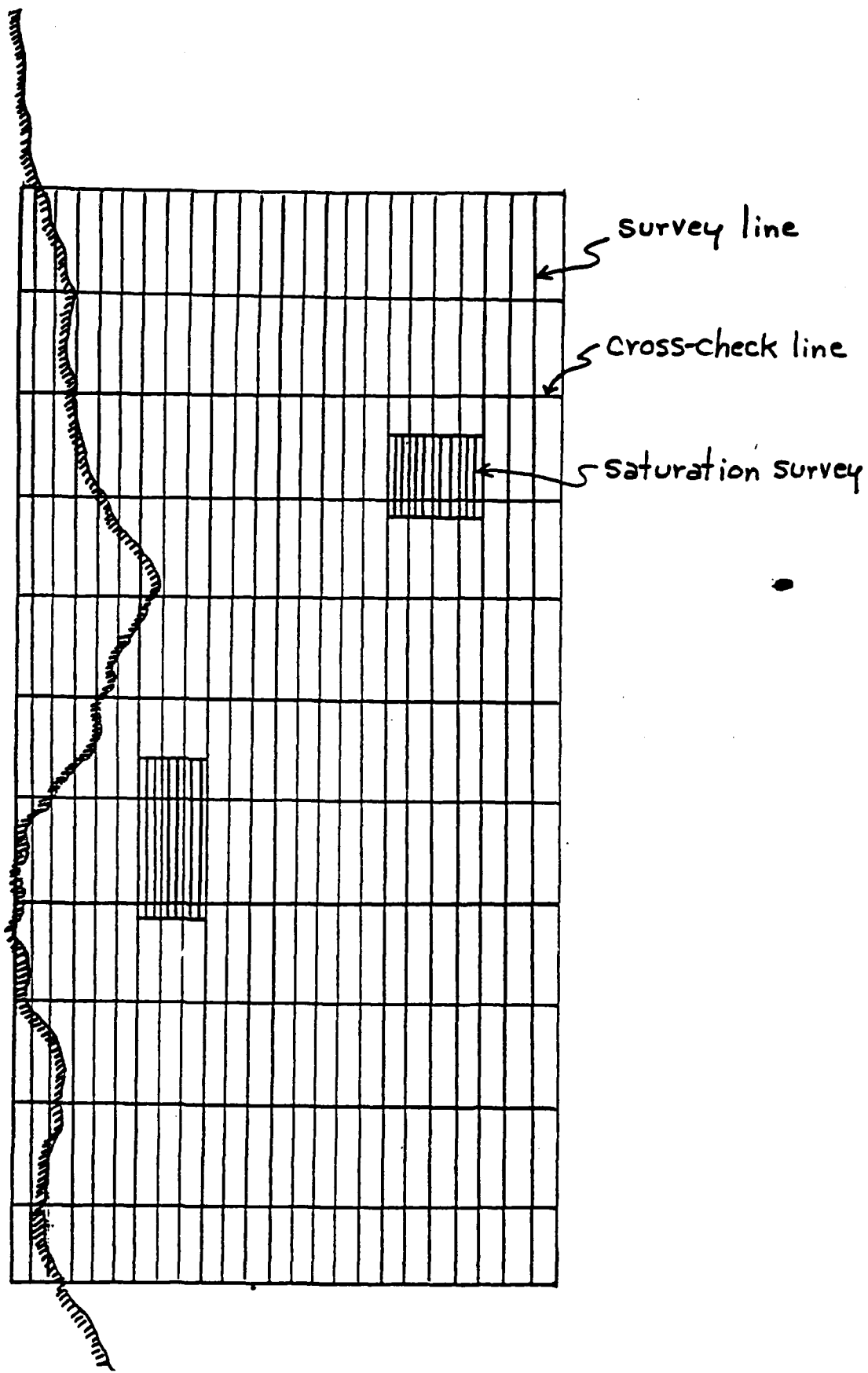


Figure 6

Three types of HALS survey lines

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